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REVIEW OF THE LATEST TECHNOLOGY IN CARTOGRAPHIC DATA ACQUISITION, MANIPULATION, STORAGE AND PRESENTATION, WITH SPECIAL EMPHASIS ON POTENTIAL APPLICATIONS IN DEVELOPING COUNTRIES: GEOGRAPHIC INFORMATION SYSTEMS: DEFINITION, FORMATION AND APPLICATION

The United States National Spatial Data Infrastructure

Paper submitted by the United States of America**

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INTRODUCTION

Over the past few decades such tools as satellite remote sensing equipment, global positioning systems, map digitizing and scanning equipment, image processing software, geographic information systems, and digital map printing systems, have allowed governmental and private sector organizations to collect, analyze, and manage electronic information related to geographic location in a way never possible before. As the technology has evolved, the value of spatial analysis has been increasingly recognized as an aid to understanding environmental and social issues that are often closely related to geographic location. These tools can integrate many different themes of data, and their usefulness has resulted in an expanded base of users.

As the user base has grown, so has the complexity of the environmental, economic and social questions being asked. The production of geographic data is burgeoning. Geographic data are now being produced by thousands of organizations in the public and private sectors. Even though many different data sets are being produced over many different geographic areas at many different levels of resolution, there are few organizations with the resources to produce and maintain all the data they need to take full advantage of these new technologies.

Since many organizations may produce and maintain geographic data about the same location, data might conceivably be shared between and among organizations, allowing organizations to direct their resources into problem solving rather than data collection. As part of a movement to streamline government operations and better manage resources, the concept of geographic data as a shared basic infrastructure to support complex decision making has lead to the development of the National Spatial Data Infrastructure (NSDI). The NSDI, as established by Executive Order in 1994, is defined as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the utilization of geospatial data." (Executive Office of the President 1994)

THE CONCEPT OF THE NATIONAL SPATIAL DATA INFRASTRUCTURE

Historially organizations that used GIS developed a "stovepipe" approach to problem solving. Separate organizations, or even separate parts of the same organization, would collect different themes of data using different combinations of software and hardware for unique applications. Information was seldom shared across organizational lines. It became increasingly clear that this approach was inefficient and did not take advantage of the integrating capabilities of GIS that allow many attributes and themes of data to be registered to one geographic location. Agencies began to

realize the value of developing a more open approach in which data that are commonly used can be shared within an organization and exchanged with groups outside the organization. For example, a county planning department, a highway department, and a tax office may each develop and maintain separate street center-line data bases. A more efficient arrangement would allow one street file to be shared among departments. This requires defining which of the three offices is responsible for updates and maintenance. Emphasis is placed on developing working relationships between and among the participants and developing standards that enable data sharing rather than on unique data collection.

This approach builds on the concept that geographic space can serve as a common denominator for problem solving. Sharing data can result in efficiencies in data development and responds to current organizational changes such as corporate "downsizing," the devolution of authority towards flatter organizational structures, and an interest in partnerships. Such an approach can create the multifaceted collections of knowledge needed to cooperatively tackle complex issues such as regional transportation planning or community sustainability.

The Federal Government, to encourage data sharing partnerships, made NSDI a major part of its effort to improve the way in which services are delivered to its citizens. A September 1993 report stated that "In partnership with state and local governments and private companies we will create a National Spatial Data Infrastructure." (Gore 1993) Implementation of the NSDI was effected through the issuance of Executive Order 12906 in April 1994. This order directs Federal agencies and the Federal Geographic Data Committee (FGDC), an interagency coordinating body, to provide federal leadership in the development of the NSDI.

ACTIVITIES TO DEVELOP THE NSDI

Initial activities to implement the NSDI concentrated on standards development, data sharing through clearinghouses, and shared production responsibilities for certain basic framework themes of data. These priorities were established through a series of public meetings of individuals from the public and private sectors and are outlined in the "1994 Plan for the National Spatial Data Infrastructure" (Federal Geographic Data Committee, 1994a) and in the Executive Order. The 1994 plan was recently updated and reissued as "A Strategy for the national Spatial Data Infrastructure (Federal Geographic Data Committee, 1997)."

Standards

Data sharing requires standards. Standards are most effective when they voluntarily emerge from wide acceptance and use within a community. Any standards process must take into account not only technical issues, but institutional, economic and behavioral issues. Standards development can often be contentious. Within the FGDC the Standards Working Group facilitates the overall process within which standards are developed by any of a dozen thematic subcommittees. Each subcommittee develops standards for data collection and content, data presentation, and data management for a

particular theme of data such as transportation, vegetation, cadastral or soils. Standards undergo extensive nationwide public review and revision that encompasses comment and testing phases and solicits input from state and local government agencies, private sector firms, and professional societies. The process may be time consuming but it increases the likelihood that standards will be used throughout the community. To date, a metadata standard has been developed and adopted in 1994; cadastral standards and a wetlands classification standard were adopted in 1996; and several standards are undergoing national review. These include a Soil Geographic Data Standard, Geospatial Positioning Accuracy Standards, and Content Standards for Digital Orthoimagery and Elevation Data.

Clearinghouse

The National Geospatial Data Clearinghouse links people seeking data with data producers. The clearinghouse is decentralized; that is data are maintained locally while information about where data can be obtained is shared through electronic networks. Potentially millions of data holdings in many different geographic locations will be cataloged and accessed through the clearinghouse.

Three elements are necessary to operate a distributed clearinghouse. Metadata, or "data about data" provides information in a data transfer and is essential to the clearinghouse concept because it serves as a catalog entry for data when made accessible on the Internet. The Content Standards for Digital Geospatial Metadata (Federal Geographic Data Committee, 1994b) establishes a consistent means to describe the quality and characteristics of spatial data. The Executive Order mandated that all Federal agencies use the standard to document new spatial data sets created after January 1995. Data producers from other levels of government, as well as the private sector, are being encouraged to use the standard to describe their data.

The second required element of the clearinghouse is the Internet. As the "network of networks" linking millions of people globally, it provides users with the ability to retrieve metadata descriptions of data sets held by data producers. Some data producers may also put the data online for downloading. Federal agencies and other organizations are being encouraged to use the Internet to provide access to metadata descriptions of their data holdings.

The third requirement in implementing the clearinghouse is the use of software tools for searching and querying data on the network. "Browsers" allow users to access "home pages" on the World-Wide Web, a graphical protocol for displaying information on the Internet by means of hypertext links. Many organizations are sharing both metadata descriptions and data by allowing users to browse their World-Wide Web sites. The FGDC is supporting the development and enhancement of searching software and the refinement of a search engine based on ISO 10163 (ANSI Z39.50) an international standard maintained by the library community, that specifies how an information search is expressed. This standard will allow for structured spatial searching of many different servers on the Internet for metadata. Current research is also underway to develop intuitive graphical map-based interfaces for searching and displaying the geographic locations and other characteristics of metadata.

Most Federal agencies and many state and local governments are currently disseminating data through sites on the Internet. Many thousands of files a month are being accessed in this manner, saving the cost of mailing maps or computer tapes. The U.S. Fish and Wildlife Service reported that in the first month of operation, approximately 29,000 digital maps from the National Wetlands Inventory were retrieved. The U.S. Geological shared 40,000 digital files with its customers during the first three months it had established an Internet presence. (Federal Geographic Data Committee, 1994c)

Framework

This activity is attempting to develop a framework of commonly-used themes of data based on shared responsibility for data creation and maintenance. These themes include digital orthoimagery, geodetic control, elevation, transportation, hydrography, governmental boundaries, and cadastral or ownership information. The framework will provide a current base on which to collect, register, or integrate other data sets for analysis. Although framework data often will only be used to support other applications, many organizations spend time and money digitizing or seeking these data sets. A common approach to building and maintaining these data sets could free an organization's resources for more pressing applications.

A Framework Working Group was formed by the FGDC in 1994 to study how to prototype the framework activity. This group consisted of representatives of Federal, state, and local government agencies. They proposed linking various existing data collection activities over specific geographic areas, recognizing that, in most instances, local governments are collecting the highest resolution data and have the most at stake in keeping their data current (Federal Geographic Data Committee 1995). Local organizations thus will play a critical role in the development and maintenance of framework data. The framework approach will allow state and Federal agencies, through collaboration with local governments, to obtain data that is more current and accurate than they would be able to create themselves.

A series of pilot studies is underway to test the assumptions of the group's report. These studies will help identify institutional issues, develop standards, possible funding initiatives, and operational guidelines for developing framework data.

ENCOURAGING PARTICIPATION IN THE NSDI

Promoting the idea of data sharing and collaboration among a diverse and widely spread set of organizations has been one of the FGDC's primary challenges. Political support from the President's Office of Management and Budget and the willingness of the Secretary of the Interior to chair the FGDC have provided a mandate and political visibility to the effort. The Secretary's involvement, in particular, has encouraged other Federal agencies to commit resources at high political levels, and has persuaded many state and local governments to elevate local needs for spatial data production and coordination. National attention has also hastened the use of standards and improved data accessibility.

The FGDC has structured its activities to allow participation by non-Federal organizations in ongoing development of the NSDI. Some of the initiatives to broaden participation are:

- Establishing coordinating groups with interest in a particular geographic area. Many states have geographic information councils that cross institutional and organizational boundaries because of their concern for solving local problems. Such councils can be important allies in the development of standards and for outreach on data sharing issues. The FGDC has a formal program to recognize these councils as partners in the development of the NSDI. Fifteen councils have been recognized thus far and many have participated in meetings with the FGDC.

- The FGDC established a Competitive Cooperative Agreements Program to encourage participation and experimentation in the development of the NSDI. These agreements are funded through an annual competitive process. Participants support collaborative activities on metadata implementation, data clearinghouse development, framework data, standards development and implementation, and other issues. A total of 62 cooperators from state and local governments, non-profit organizations, academic institutions, and private industry have been funded in the three years since this program began.

- The FGDC conducts numerous training courses, workshops and presentations about its activities at national, state, regional and user group conferences. The FGDC and its various subcommittees publish a newsletter and several technical reports each year. These can be accessed electronically from the FGDC home page on the World-Wide Web <http://www.fgdc.gov>

FUTURE EVOLUTION OF THE NSDI

The NSDI is constantly evolving as telecommunications and GIS technologies change. Thus, predicting the future is difficult. Institutional, social, and economic issues will play a large role in future directions. Some of the questions that will certainly impact the future of the NSDI are listed below:

Economic and institutional:

- What are the implications of cost-recovery policies on the evolution of the NSDI, and how will the imposition of such fees impact the availability and quality of spatial data?
- Should copyright be applied to spatial data?
- What should be the data collection and maintenance roles of federal, state, and local agencies over a given piece of geography, and how do these relate to private sector initiatives?
- What incentives will promote interagency coordination; what are the constraints?
- What mechanism, if any, is required to oversee the NSDI?

Standards:

- What standards will promote data sharing?

- How are standards best created? By the federal government? The private sector?
- Who should be responsible for maintaining standards?
- What mechanisms or incentives will encourage the use of standards?
- Is the concept of a "certified" data set useful, and, if so, who would certify?

Technical issues

- How can different data sets from different computers be used across a distributed network?
- What is the best way to promote interoperability? Through transfer standards? Data structure specifications? And what roles and incentives are there for the private sector?
- How can multiresolution data sets collected by different organizations best be integrated and used?
- Who defines features and on what basis?
- What is the best way to represent metadata to the end user?

CONCLUSION

Efforts so far to develop the NSDI have focused on very specific problems such as: Who has what data? How can data sets be accessed? Are these data suitable for my application? Future efforts will depend on the community's ability to agree on many institutional, policy, economic and technical issues. These challenges will only be overcome and the NSDI developed through the creation of partnerships, placing responsibility for data creation at local levels, and collaborating to resolve issues.

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